


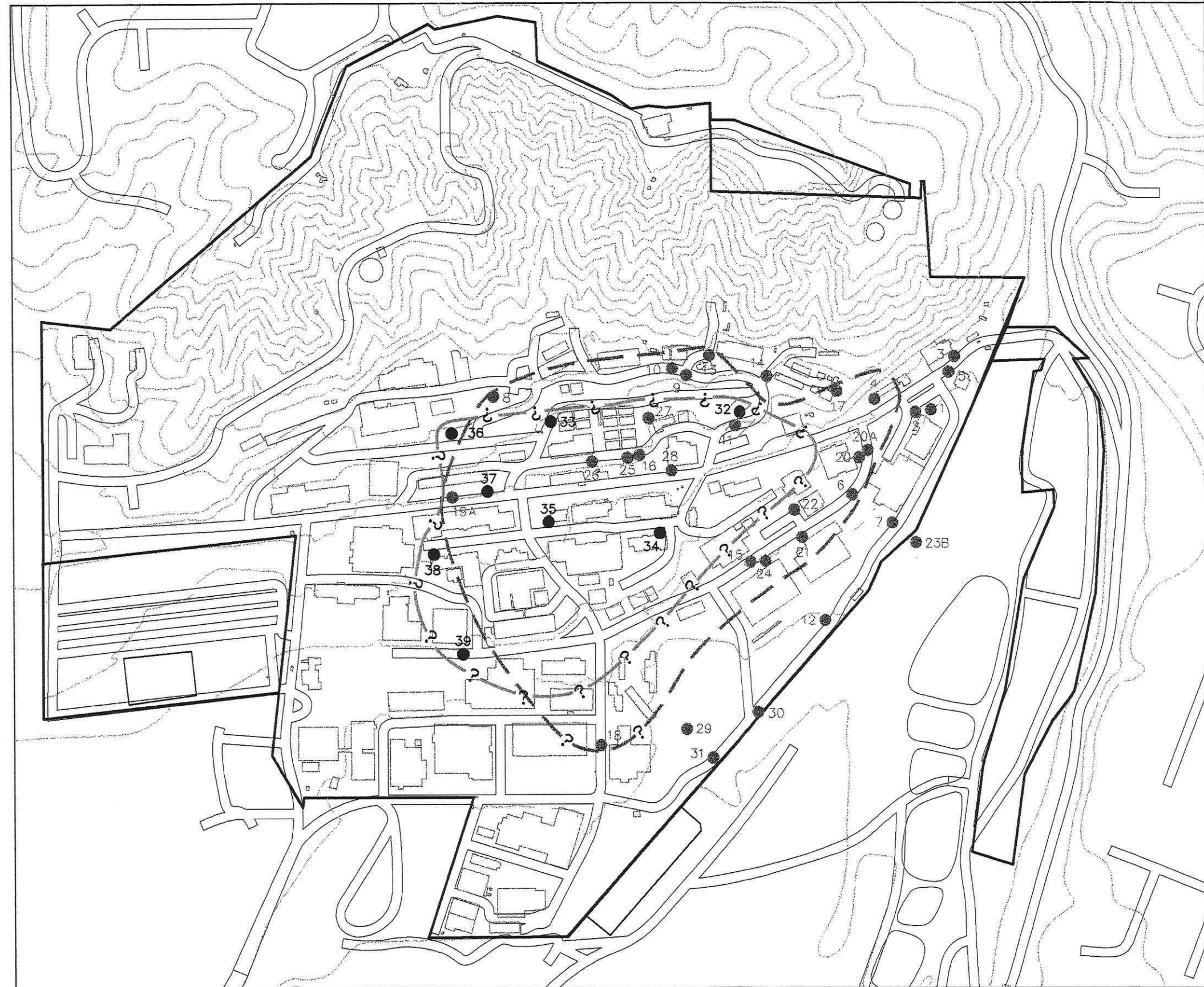
Explanation	
25	Soil Vapor Sample Point and Depth
43	Concentrations of Carbon Tetrachloride ($\mu\text{g/L}$ -Vapor)
ND	Non-Detect @ Laboratory Detection Limit of $1.0\mu\text{g/L}$ -Vapor
W	Sample Port Waterlogged; No Sample Collected
-----	Estimated Approximate Groundwater Elevation During Event 7
(P)	Perched Groundwater

FIGURE 1-16

VERTICAL EXTENT OF CARBON TETRACHLORIDE FROM
WEST TO EAST ACROSS THE JPL SITE, EVENT 7
JUNE, 1998

Jet Propulsion Laboratory
Pasadena, California

 FOSTER WHEELER ENVIRONMENTAL
CORPORATION



Explanation

- 39 Soil Vapor Wells Sampled During Event 7
- 31 Soil Vapor Wells Not Sampled During Event 7

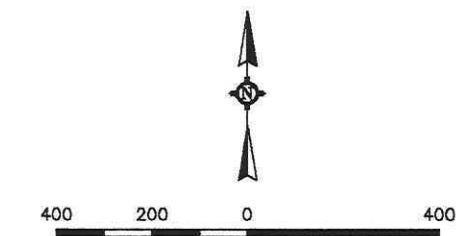
Countours:

1. Represent minimum known areal distribution based on sampling event.
2. Not queried where some horizontal control exists.

— ? — Freon 113 Detected During Event 7

/// Concentrations of Freon 113 Exceeding 100 $\mu\text{g/L}$ -Vapor at an Individual Sample Point

--- Freon 113 Detected During Events 2 and 3



SCALE IN FEET

Source: USGS, 7.5 Minute Topographic Map Pasadena, CA 1966, Revised 1988, 1994.

FIGURE 1-17

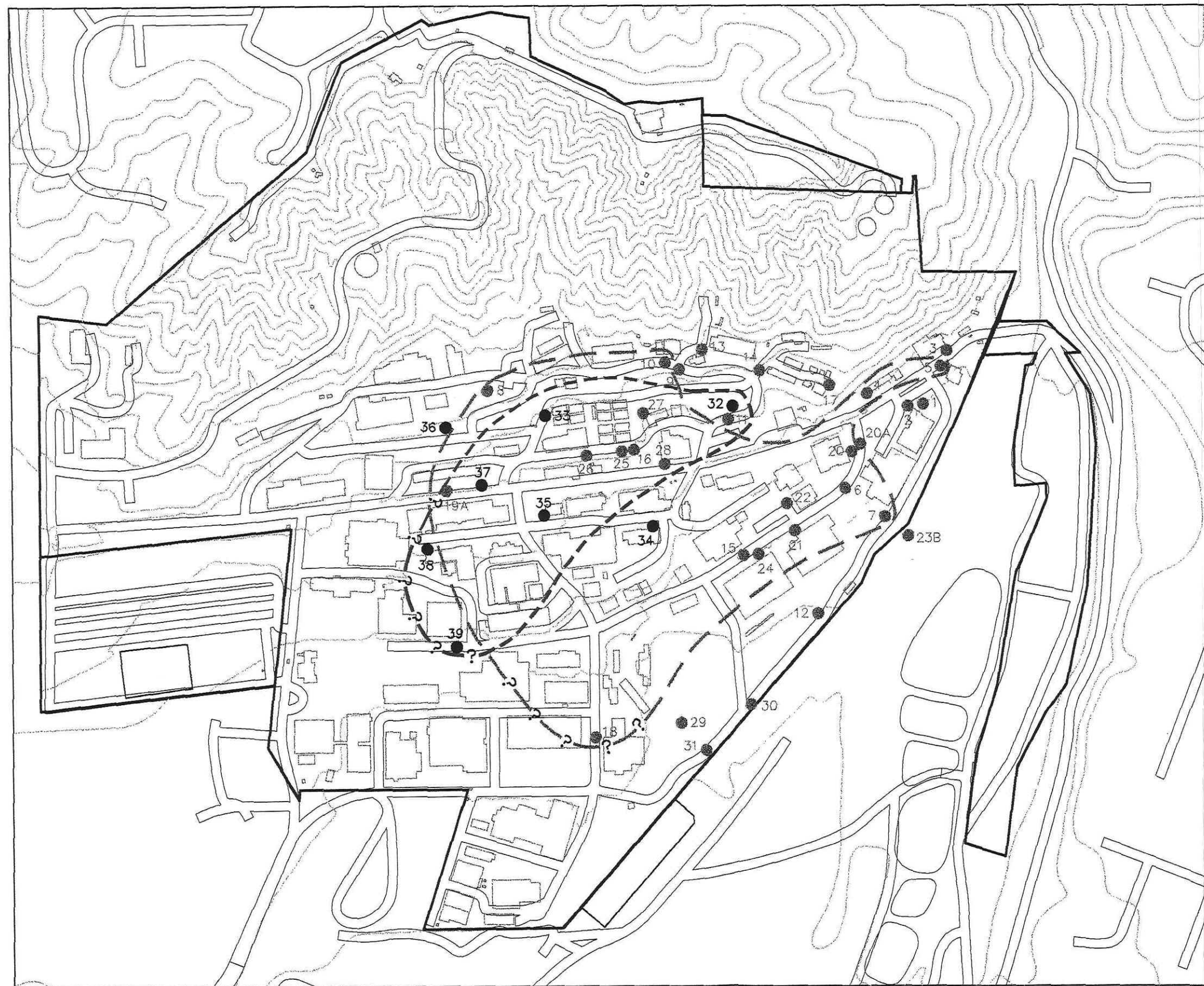
FREON 113, EVENT 7

JUNE, 1998

Jet Propulsion Laboratory
 Pasadena, California



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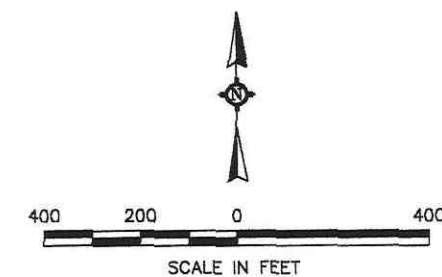
Explanation

- 39 Soil Vapor Wells Sampled During Event 7
- 31 Soil Vapor Wells Not Sampled During Event 7

Countours:

1. Represent minimum known areal distribution based on sampling event.
2. Not queried where some horizontal control exists.

- ? - Trichloroethene (TCE) Detected During Event 7
- - - Trichloroethene (TCE) Detected During Events 2 and 3



Source: USGS, 7.5 Minute Topographic Map
 Pasadena, CA 1966, Revised 1988, 1994.

FIGURE 1-19

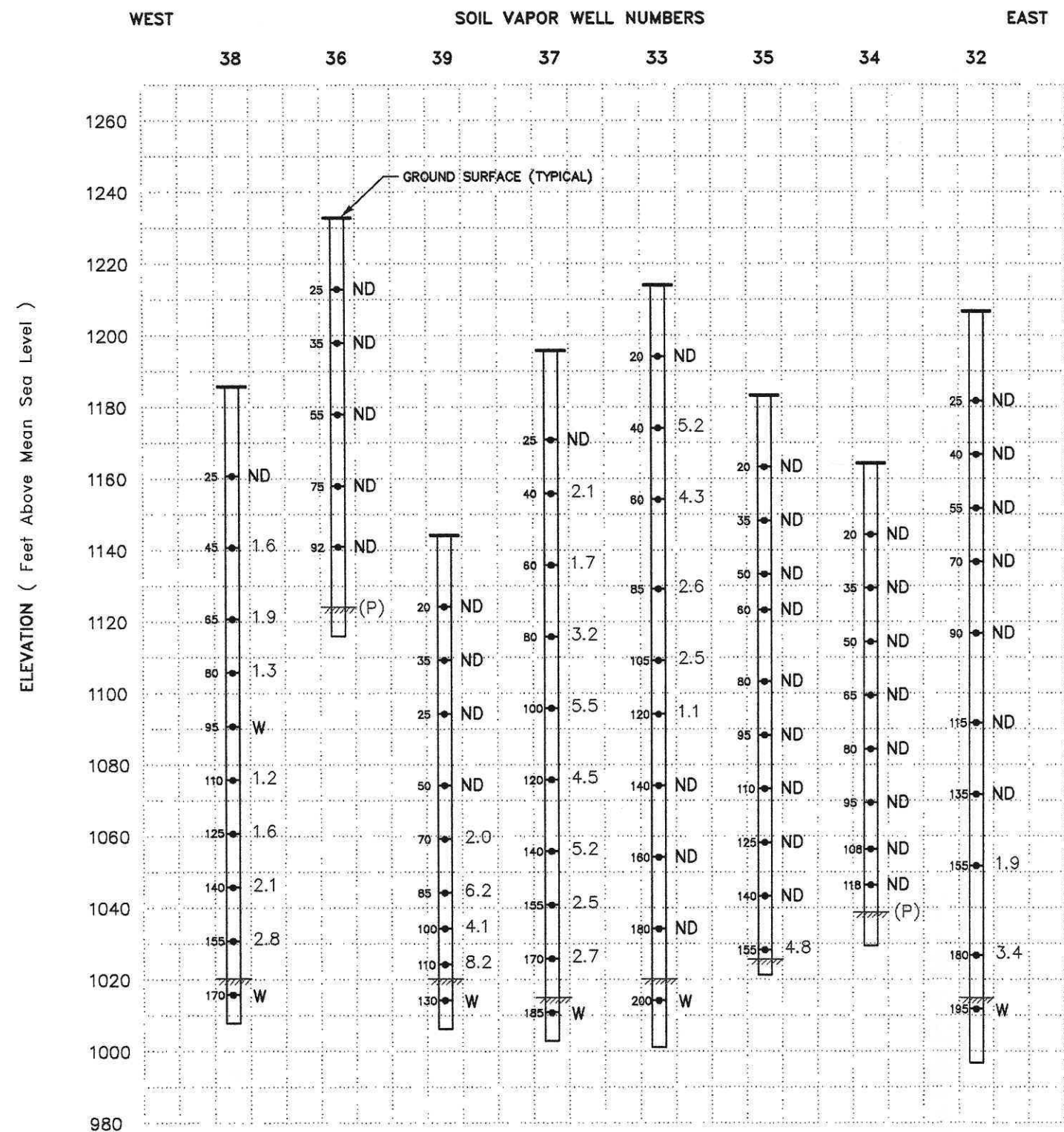
TRICHLOROETHENE, EVENT 7

JUNE, 1998

Jet Propulsion Laboratory
 Pasadena, California



FOSTER WHEELER ENVIRONMENTAL
 CORPORATION



Explanation	
25	Soil Vapor Sample Point and Depth
5.2	Concentrations of Trichloroethene (µg/L-Vapor)
ND	Non-Detect @ Laboratory Detection Limit of 1.0 µg/L-Vapor
W	Sample Port Waterlogged; No Sample Collected
////	Estimated Approximate Groundwater Elevation During Event 7
(P)	Perched Groundwater

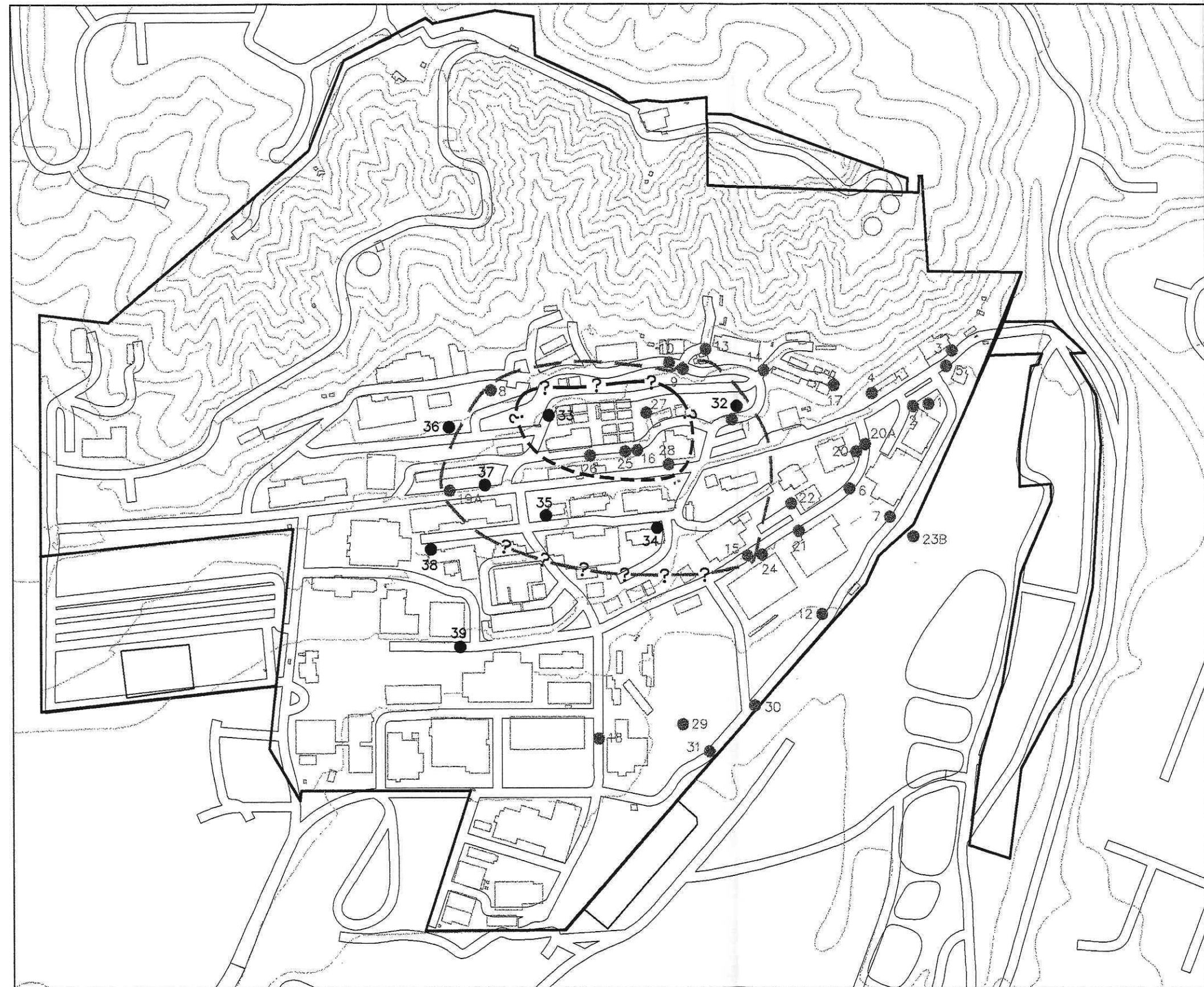
FIGURE 1-20

VERTICAL EXTENT OF TRICHLOROETHENE FROM WEST TO EAST ACROSS THE JPL SITE, EVENT 7 JUNE, 1998

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

I:\1572-JPL\DWG\OU2\FS99\FIG1-21.DWG
PLOT/UPDATE: OCT 23 1999 12:21:06



Explanation

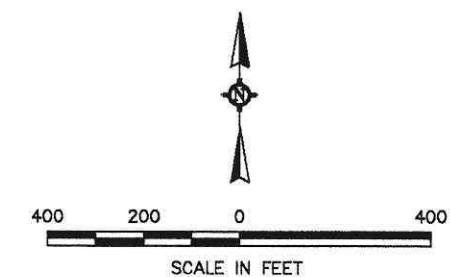
- 39 Soil Vapor Wells Sampled During Event 7
- 31 Soil Vapor Wells Not Sampled During Event 7

Contours:

1. Represent minimum known areal distribution based on sampling event.
2. Not queried where some horizontal control exists.

— ? — 1,1-Dichloroethene (1,1-DCE) Detected During Event 7

--- Lateral Extent of 1,1-Dichloroethene (1,1-DCE) Detected During Events 2 and 3



Source: USGS, 7.5 Minute Topographic Map
Pasadena, CA 1960, Revised 1988, 1994.

FIGURE 1-21

1,1-DICHLOROETHENE, EVENT 7

JUNE, 1998

Jet Propulsion Laboratory
Pasadena, California



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Explanation

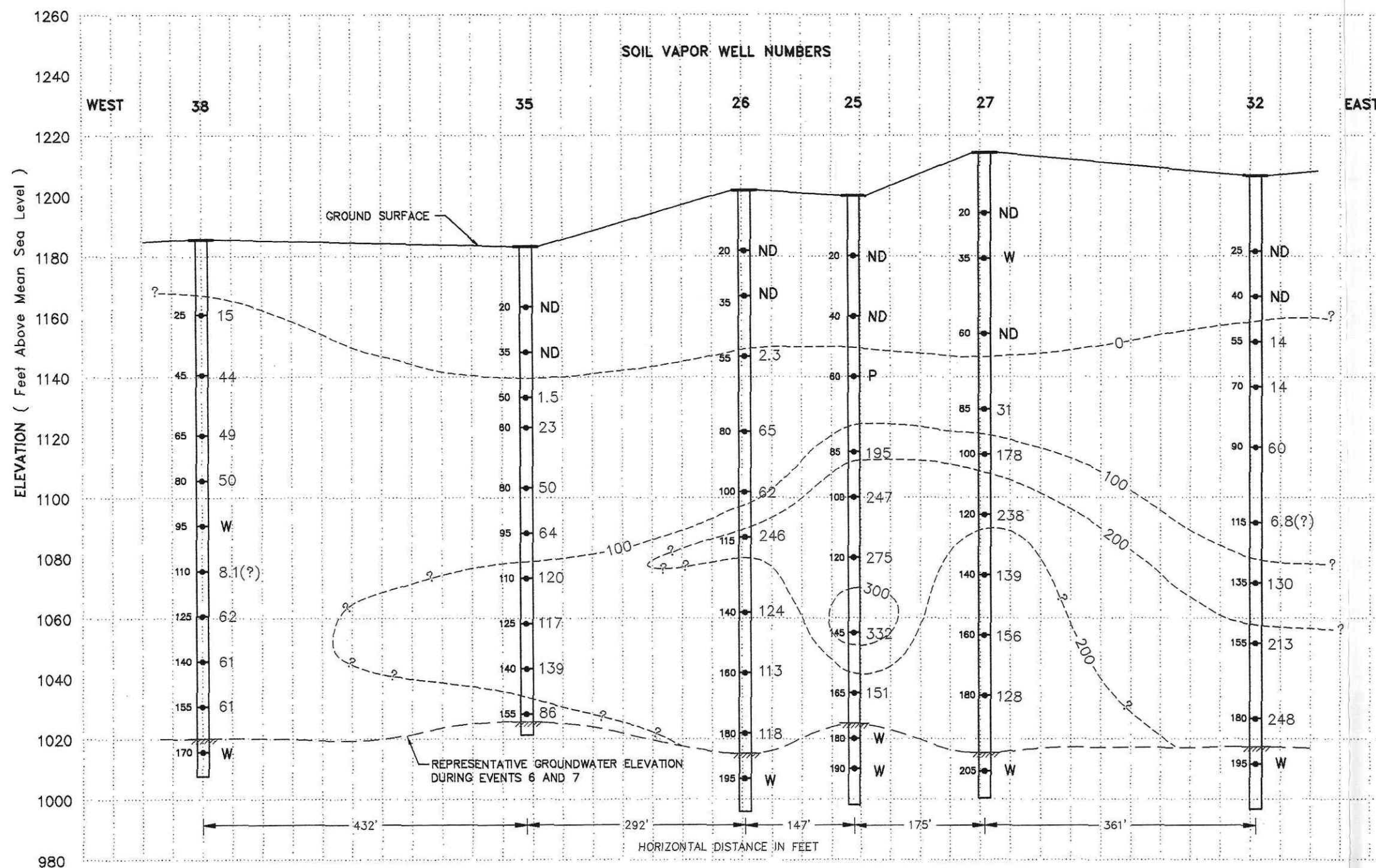
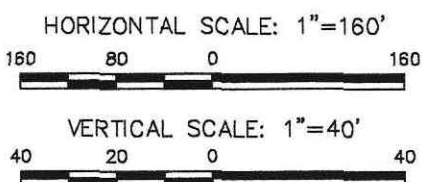
- 25 • Soil Vapor Sample Point and Depth
- 139 Concentrations of Total VOCs ($\mu\text{g/L}$ -Vapor)
- ND Non-Detect @ Laboratory Detection Limit of 1.0 $\mu\text{g/L}$ -Vapor
- P Sample Port Plugged; No Sample Collected
- W Sample Port Waterlogged; No Sample Collected

Contours:

- Intervals in 100 $\mu\text{g/L}$ -Vapor.
- Queried where spatial control is lacking.

Note:

Location of cross-section is shown on Figure 1-14.



NOTE:

THE CONCENTRATION SUMS PRESENTED INCLUDE THE HIGHEST RESULTS OBTAINED FROM EITHER EVENT.

FIGURE 1-23

REPRESENTATIVE HORIZONTAL AND VERTICAL
DISTRIBUTION OF TOTAL VOCs DURING THE TIME
INTERVAL FOR EVENTS 6 AND 7
MAY-JUNE, 1998

Jet Propulsion Laboratory
Pasadena, California



FOSTER WHEELER ENVIRONMENTAL
CORPORATION

Explanation

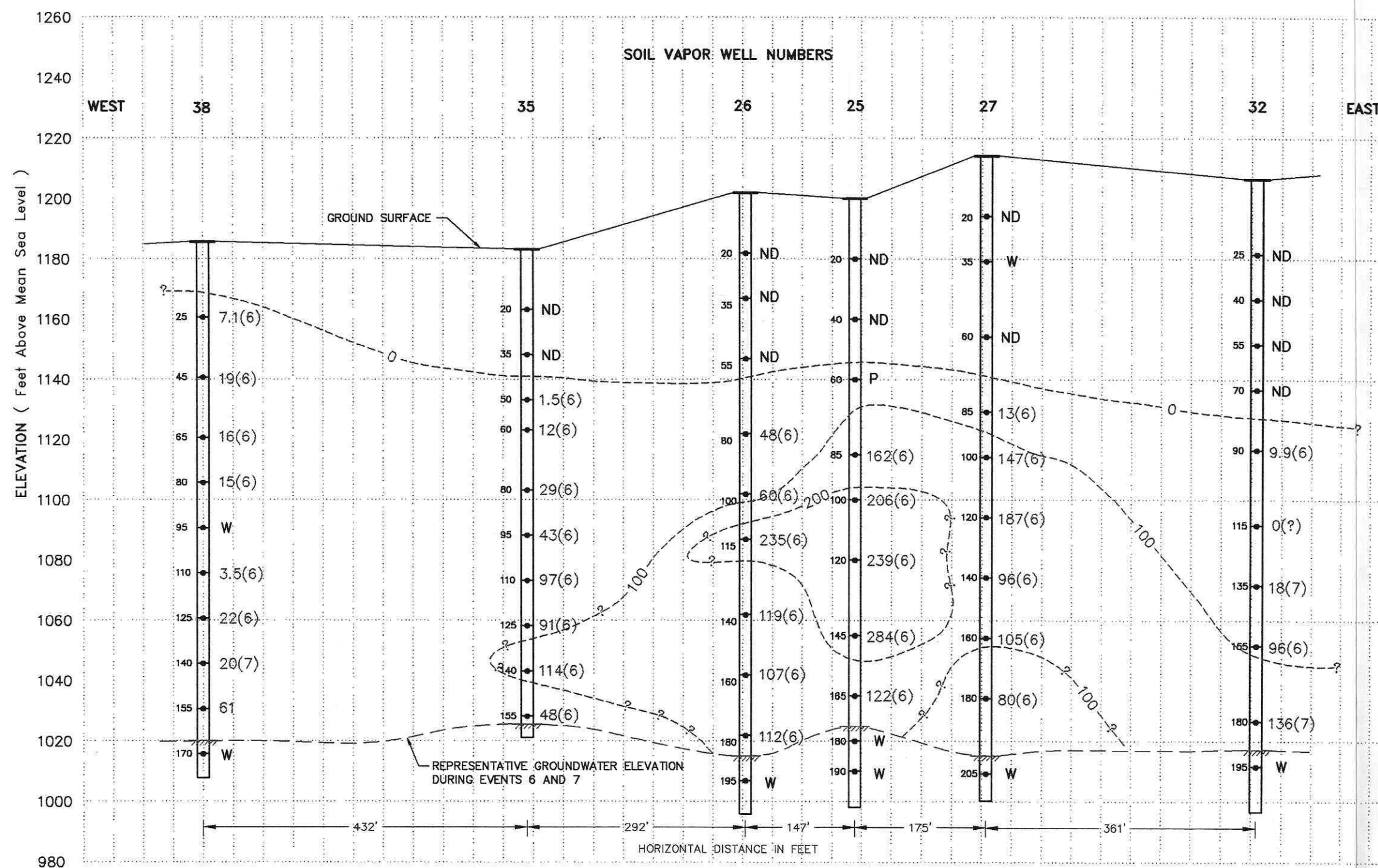
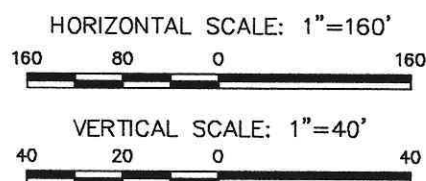
- 25 → Soil Vapor Sample Point and Depth
- 187 Concentrations of Carbon Tetrachloride ($\mu\text{g/L}$ -Vapor)
- (6) Indicates Sample Event From Which Results Came
- ND Non-Detect @ Laboratory Detection Limit of $1.0 \mu\text{g/L}$ -Vapor
- P Sample Port Plugged; No Sample Collected
- W Sample Port Waterlogged; No Sample Collected

Contours:

- Intervals in $100 \mu\text{g/L}$ -Vapor.
- Queried where spatial control is lacking.

Note:

Location of cross-section is shown on Figure 1-14.



NOTE:

HIGHEST CONCENTRATION FROM EITHER EVENT ARE PRESENTED.

FIGURE 1-24

REPRESENTATIVE HORIZONTAL AND VERTICAL
DISTRIBUTION OF CARBON TETRACHLORIDE
DURING THE TIME INTERVAL FOR EVENTS 6 AND 7
MAY-JUNE, 1998

Jet Propulsion Laboratory
Pasadena, California



FOSTER WHEELER ENVIRONMENTAL
CORPORATION

Explanation

- 25 → Soil Vapor Sample Point and Depth
- 31 Concentrations of Freon 113 ($\mu\text{g/L}$ -Vapor)
- (6) Indicates Sample Event From Which Results Came
- ND Non-Detect @ Laboratory Detection Limit of 1.0 $\mu\text{g/L}$ -Vapor
- P Sample Port Plugged; No Sample Collected
- W Sample Port Waterlogged; No Sample Collected

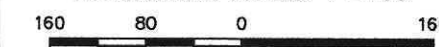
Contours:

- 1. Intervals in 50 $\mu\text{g/L}$ -Vapor.
- 2. Queried where spatial control is lacking.

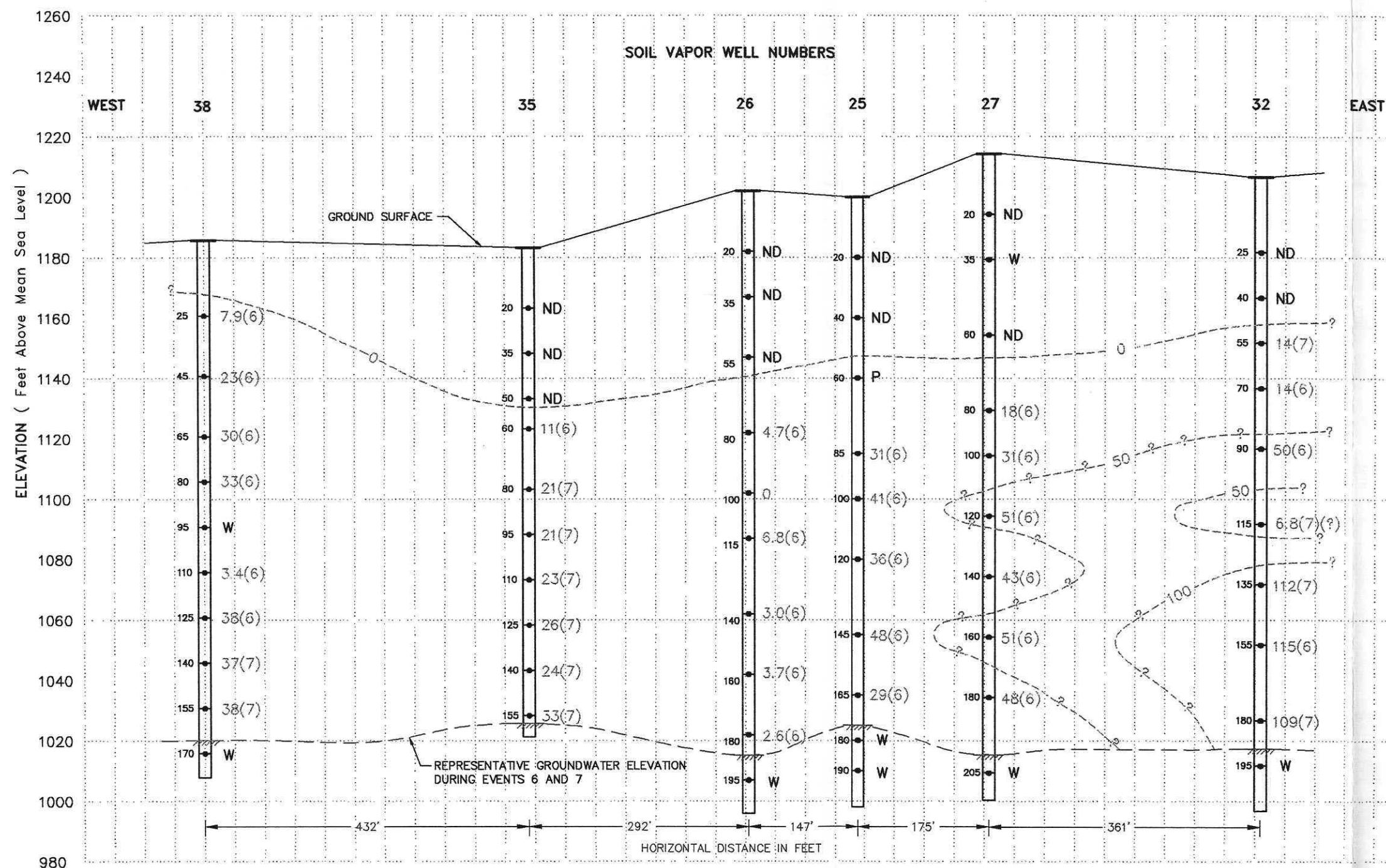
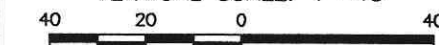
Note:

Location of cross-section is shown on Figure 1-14.

HORIZONTAL SCALE: 1"=160'



VERTICAL SCALE: 1"=40'



NOTE:

HIGHEST CONCENTRATION FROM EITHER EVENT ARE PRESENTED.

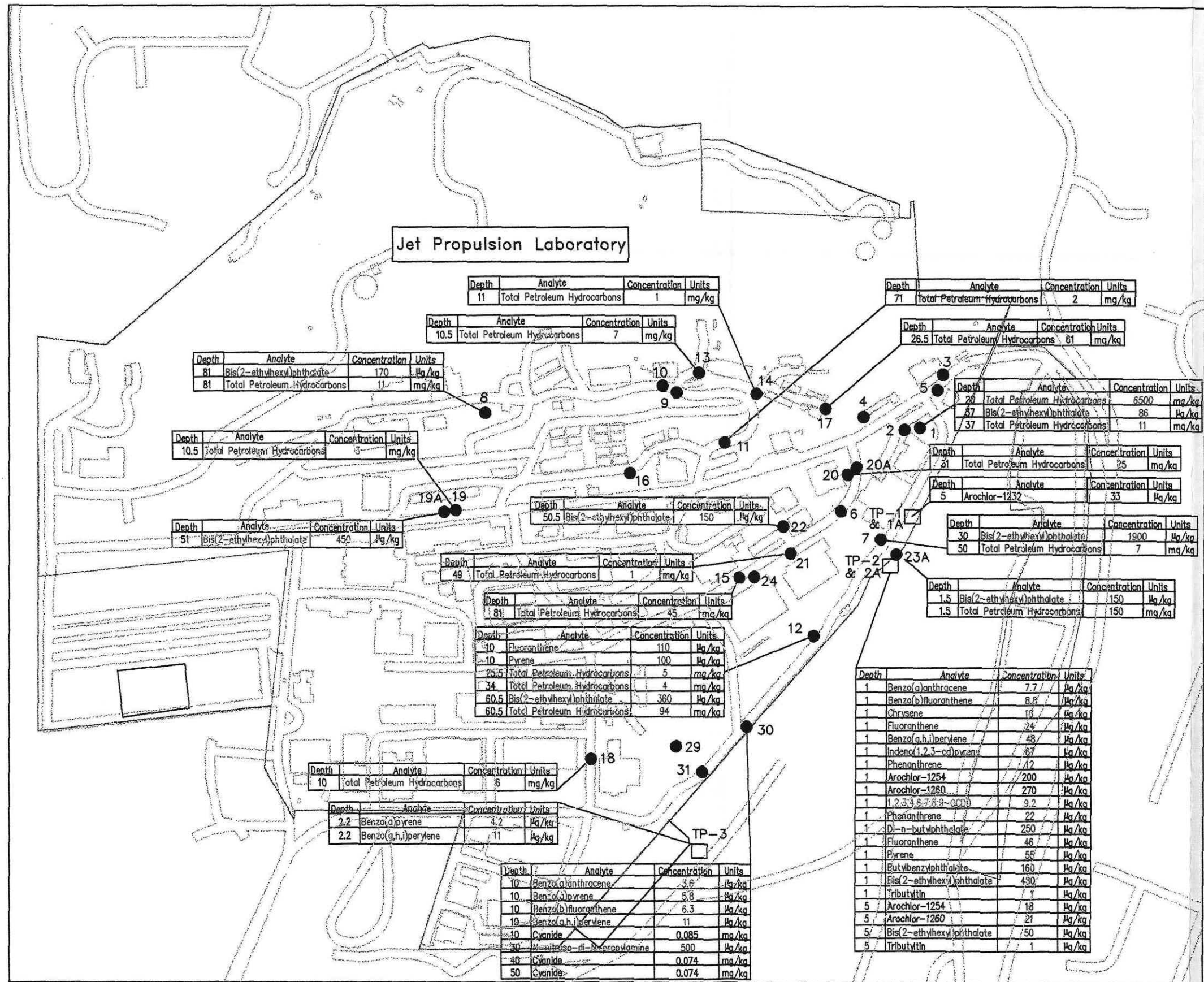
FIGURE 1-25

REPRESENTATIVE HORIZONTAL AND VERTICAL
DISTRIBUTION OF FREON 113 DURING
THE TIME INTERVAL FOR EVENTS 6 AND 7
MAY-JUNE, 1998

Jet Propulsion Laboratory
Pasadena, California



FOSTER WHEELER ENVIRONMENTAL
CORPORATION

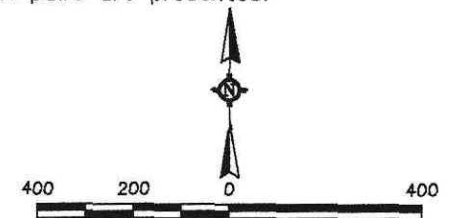


Explanation

- 39 Soil Boring Completed During
RI Investigation
- TP-1
& 1A Test Pit Location
- Total Petroleum Hydrocarbons
(EPA Method 418.1)
- Semivolatile Organic Compounds
(EPA Method 8270)
- Polycyclic Aromatic Hydrocarbons
(EPA Method 8310)
- Poly Chlorinated Biphenyls
(EPA Method 8081)
- Dioxins
(EPA Method 8280)
- Cyanide
(EPA Method 335.3)
- Tributyltin
(No EPA Method)

mg/kg	Milligrams per kilogram
µg/kg	Micrograms per kilogram

NOTE:
The higher concentrations from the test pit pairs are presented.



SCALE IN FEET

Source: USGS, 7.5 Minute Topographic Map
Pasadena, CA 1968, Revised 1988, 1994.

FIGURE 1-26

CONCENTRATIONS OF ORGANIC COMPOUNDS
AND CYANIDE DETECTED IN SOIL
DURING THE OU-2 RI

Jet Propulsion Laboratory
Pasadena, California



FOSTER WHEELER ENVIRONMENTAL
CORPORATION

2.0 IDENTIFICATION OF POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Identified in this section are the potential applicable or relevant and appropriate requirements (ARARs) for the remedial alternatives described in this FS. The identification of ARARS is a key component of the planning, evaluation, and selection of remedial actions. Also identified in this section are other guidance and criteria "to be considered" (TBCs) in selecting a remedy for JPL.

2.1 DEFINITION OF ARARS AND OTHER CRITERIA OR GUIDELINES TO BE CONSIDERED

Section 121(d) of CERCLA requires remedial actions at CERCLA sites to attain any federal or state environmental standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate unless any such standard requirement, criterion or limitation is waived. Federal ARARs may include requirements under any federal environmental laws (e.g., the Safe Drinking Water Act (SDWA), the Clean Water Act (CWA), and the Clean Air Act (CAA)). Only promulgated, legally enforceable environmental or facility-siting laws and regulations that are timely identified and are more stringent or broader in scope than federal requirements qualify as State ARARs. Several California laws give local agencies the authority to develop regulations that implement state requirements. As a result, some local regulations are also potential ARARs.

According to the National Contingency Plan (NCP) (40 CFR Part 300), "applicable," "relevant and appropriate," and "TBCs" are defined as follows:

- **Applicable requirements** are those standards, requirements, criteria, or limitations in regulations promulgated by federal or state agencies and in federal or state statutes that specifically address a substance, remedial activity, location, or other circumstances found at a CERCLA site.
- **Relevant and appropriate requirements** are those standards, requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a substance, remedial activity, location, or other circumstances at a CERCLA site, address situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.
- **TBCs** consist of advisories, criteria, or guidance developed by federal agencies, states, or local agencies, which are not set forth in regulations or statutes and which may be useful in developing CERCLA remedies. They are not legally binding and do not have status as potential ARARs.

The hazardous substances present, the remedial actions contemplated, the physical characteristics of the site, and other appropriate factors are considered when determining whether a requirement is "applicable" or "relevant and appropriate."

Pursuant to CERCLA §121 and the NCP, only substantive requirements are ARARs. In addition, under CERCLA §121(e), federal, state, and local permits are not required for those portions of a CERCLA response action that are conducted entirely within the CERCLA site.

2.2 CLASSIFICATION OF ARARS

ARARs and TBCs can be divided into three categories: chemical-specific, location-specific, and action-specific. Each potential remedial alternative will be evaluated to determine compliance with identified ARARs or TBCs. The three ARAR and TBC categories are summarized below:

- **Chemical-specific** requirements are health- or risk-based concentration limits, or numerical values for various environmental media (i.e., groundwater, surface water, air, and soil) that are established for a specific chemical. These ARARs set limits on concentrations of specific hazardous substances, pollutants, and contaminants in the environment. Examples of this type of ARAR include state and federal drinking water standards.
- **Location-specific** requirements set restrictions on certain types of activities based on site characteristics and location. Federal and state location-specific ARARs are restrictions placed on the concentration of a contaminant or the activities to be conducted because they are in a specific location. An example of a location specific ARAR is a prohibition on the disposal of a hazardous waste in a solid waste landfill.
- **Action-specific** requirements are technology- or activity-based requirements that are triggered by the type of remedial activities under consideration. Examples are RCRA regulations for waste treatment, storage, or disposal.

2.3 IDENTIFICATION OF POTENTIAL ARARS

Neither CERCLA nor the NCP provide explicit standards for determining whether a particular remedy will result in an adequate cleanup at a particular site. Rather, CERCLA recognizes that each site has unique characteristics that must be evaluated to determine which federal or state requirements are ARARs.

Federal, state, and local ARARs and TBCs listed herein are based on the current set of remedial alternatives identified for JPL, on available analytical data, and on a review of potential ARARs for sites with similar circumstances.

Since a remedy for JPL has not yet been selected, all ARARs identified in this section are preliminary. A final determination of the ARARs for JPL will be included in the Record of Decision (ROD).

2.3.1 Potential Chemical-Specific ARARs

Chemical-specific ARARs are health- or risk-based concentration limits that are established for a specific chemical that may be present in the environment, or that may be discharged during remedial activities.

With regard to contaminants of interest at JPL, investigations were carried out to characterize both soil and soil vapor. Several constituents were sporadically detected at low concentrations during the soil investigation. Results of the HHRA indicated only two polychlorinated biphenyl congeners (Arochlor-1254 and Arochlor-1260), arsenic, and hexavalent chromium as preliminary COPCs in the soil. However, these constituents were detected with very low frequency (see Section 1.3.7.2) and/or their potential for migration is considered very low (see Section 1.3.8). Calculated risk associated with these constituents was determined to be negligible and within acceptable EPA target risk ranges (see Section 1.3.9.2). Therefore, the soil COPCs are not considered in this FS.

Results of the soil vapor investigation indicated that VOCs, consisting primarily of carbon tetrachloride (CCl_4), trichloroethene (TCE), 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113), and 1,1-dichloroethene (1,1-DCE) were consistently detected in soil-vapor beneath the north-central portion of the site. Results of the HHRA did not identify any of the VOCs in soil vapor as COPCs. However, because the areal extent of these compounds in soil vapor is relatively substantial and VOCs (notably CCl_4 and TCE) have been of concern in groundwater beneath the site, this FS focuses on the soil-vapor, and considers the four primary VOCs detected. The chemical-specific federal and state ARARs that address these contaminants are discussed below. A summary of potential chemical-specific ARARs, including a brief description, regulatory citation, and a determination as to “applicability” or “relevance and appropriateness” to the proposed remedial action is provided in Table 2-1.

2.3.1.1 Safe Drinking Water Act

EPA has established maximum contaminant levels (MCLs) (40 CFR Part 141) under the Safe Drinking Water Act (SDWA) to protect public health from contaminants that may be found in drinking water sources. MCLs are enforceable standards that are applicable at the tap for water that is delivered directly to 25 or more people or which may be supplied to 15 or more service connections.

Under the SDWA, EPA has also designated maximum contaminant level goals (MCLGs) (40 CFR Part 141), which are health-based goals that may be more stringent than MCLs. MCLGs are based entirely on health considerations and do not take cost or the feasibility of achieving them into account. MCLGs are set at levels, including an adequate margin of safety, where no known or anticipated adverse health effects would occur. MCLs are required to be set as close as feasible to the respective MCLGs, taking into consideration available treatment technologies, analytical capabilities, and other factors (including cost). Although not legally applicable, MCLGs may be relevant and appropriate in circumstances where multiple contaminants or

multiple pathways of exposure present unacceptable health risks (EPA, Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites, OSWER Directive 9283.1-2, 1988b).

Under the NCP (40 CFR Section 300.430(e)(2)(B)) concerning ARARs, remedial actions for groundwater that is a current or potential source of drinking water must generally attain MCLs and nonzero MCLGs. The groundwater at JPL is a current source of drinking water, and, therefore, MCLs and nonzero MCLGs are applicable. The remedy selected for soil contamination at JPL will consider the soil to groundwater contaminant migration pathway, and would require cleanup levels for soil to be protective of beneficial uses of the groundwater.

2.3.1.2 California Safe Drinking Water Act

California has established standards for sources of public drinking water, under the California Safe Drinking Water Act of 1976 (Health and Safety Code (H&SC) §§ 4010.1 and 4026(c)). Some state MCLs are more stringent than the corresponding federal MCLs. In these instances, the more stringent state MCLs are applicable to JPL. There are also some chemicals that lack federal MCLs. Where state MCLs exist, they are also applicable for these chemicals. The California secondary MCLs contained in Title 22 CCR Section 64449 pertain to minimum aesthetic qualities of drinking water. These enforceable limits are applicable to JPL if treated groundwater is directed for domestic use. Therefore, the remedy selected for soil contamination at JPL will consider the soil to groundwater contaminant migration pathway, and would require cleanup levels for soil to be protective of beneficial uses of the groundwater.

2.3.1.3 State Water Resources Control Board, Resolution 68-16

While there are no specific numerical regulatory standards for soil cleanup, Resolution 68-16 (antidegradation policy) applies to the establishment of cleanup levels for groundwater and for soils which threaten water quality. At a minimum, Resolution 68-16 would be relevant and appropriate to remedial alternatives for the unsaturated zone, and would require cleanup levels for soil to be protective of beneficial uses of the groundwater.

2.3.1.4 State Water Resources Control Board, Resolution 92-49

Resolution 92-49 (Cleanup and Abatement Policy) establishes cleanup and abatement policies and procedures for those cases of pollution wherein it is not reasonable to restore water quality to background levels. Under this policy, case-by-case cleanup levels for the restoration of water quality must, at a minimum:

- Consider all beneficial uses of the waters;
- Cannot result in water quality less than that prescribed by the Basin Plan and policies adopted by the State and Regional boards; and
- Be consistent with maximum benefit to the people of the State.

Resolution 92-49 is relevant and appropriate to NASA's remedial action plan for soil in that it addresses protection of groundwater through the soil to groundwater migration pathway.

2.3.1.5 Los Angeles Regional Water Quality Control Board, Los Angeles River Basin Plan

The LARWQCB Basin Plan identifies beneficial uses, water quality objectives, and incorporates SWRCB Policy (Resolution 68-16) "Statement of Policy With Respect to Maintaining High Water Quality in California." The Basin Plan identifies the beneficial uses of surface and groundwater in the Los Angeles River Basin watershed and water quality objectives necessary to protect these beneficial uses. Waters designated as Municipal and Domestic Supply have California MCLs as water quality objectives. Since the Basin Plan identifies Municipal and Domestic Supply as a potential beneficial use of the Arroyo Creek and the Monk Hill Subbasin, California MCLs are applicable to remedial actions involving potential impact to the Monk Hill Subbasin. Therefore, the remedy selected for soil contamination at JPL will consider the soil to groundwater contaminant migration pathway, and would require cleanup levels for soil to be protective of beneficial uses of the groundwater.

2.3.1.6 Title 23 California Code of Regulations, Division 3, Chapter 15, Article 5, Section 2550

This regulation contains monitoring requirements for waste management units, including unauthorized waste discharges to land, and establishes water quality protection standards for corrective action including concentration limits for constituents of concern at background levels unless infeasible to achieve. Cleanup levels greater than background must be the lowest economically and technologically achievable, must consider exposure to other media, and must consider combined toxicologic effects of pollutants. The substantive provisions of this section may be relevant and appropriate for remediation of the unsaturated zone at JPL.

2.3.2 Potential Location-Specific ARARs

Federal and state location-specific ARARs are restraints placed on the activities to be conducted because they are in a specific location. Examples of location-specific ARARs are requirements restricting actions in floodplains, wetlands, historic places, and sensitive ecosystems or habitats. Location-specific ARARs can be considered as a subset of action-specific ARARs. They do not drive the need for a CERCLA action to occur, but, if CERCLA action is otherwise appropriate, they may constrain the range of appropriate action. A summary of potential location-specific ARARs, including a brief description, regulatory citation, and a determination as to "applicability" or "relevance and appropriateness" to the proposed remedial action is provided in Table 2-2. Brief discussions are also provided below.

2.3.2.1 Federal Facilities Compliance Act

The FFCA requires federal facilities, which includes NASA's JPL facility, to comply with all federal, state, and local requirements for solid and hazardous waste management. The FFCA is relevant to remedies that may involve waste management.

2.3.2.2 National Historic Preservation Act

Under this statute, if a federal undertaking affects any district, site, building, structure or object that is listed on or eligible for listing on the National Register of Historic Places, the responsible official shall comply with the procedures for consultation and comment promulgated by the Advisory Council on Historic Preservation. NASA has an obligation to determine if any district, site, building, structure or object listed or eligible to be listed on the National Register of Historic Places would be affected by the proposed remedial activities. It is unlikely that property with historic, architectural, archeological, or cultural value, located within the vicinity of JPL, will be impacted by remedial actions. However, a historic, archeological, architectural and cultural resource review of surrounding and on-site property must be conducted prior to implementation of remedial actions involving structure demolition, construction or intrusive groundwork.

2.3.2.3 Archaeological Resources Protection Act

This statute and implementing regulations establish requirements for the evaluation and preservation of historical and archaeological data that may be destroyed through alteration of terrain as a result of a federal project or a federally approved activity or program. This act is potentially applicable for remedial alternatives that involve construction around archaeological sites. Review of archaeological and historical data of surrounding and on-site property may need to be conducted prior to implementation of remedial actions involving structure demolition or construction or intrusive groundwork.

2.3.2.4 Executive Order 11988 – Protection of Floodplains

In accordance with Executive Order 11988, federal agencies are required to avoid, to the extent possible, adverse effects associated with direct or indirect development in a floodplain. If avoidance is not possible, mitigation of the adverse effect is required. Therefore, this regulation may be applicable to the JPL site depending on the nature of the remedy.

2.3.2.5 Executive Order 11990 – Protection of Wetlands

Executive Order 11990 requires Federal agencies, in carrying out their responsibilities, to take action to minimize the loss, destruction, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands. The Arroyo Seco has not been formally identified as a “wetland”, and it is unlikely any remediation activities for soil will be conducted in or around Arroyo Seco. Nevertheless, this provision may be applicable to the JPL site depending on the nature of the remedy.

2.3.2.6 Statement of Exclusion

The areal extent of soil contamination and the proposed area for installation and operation of a remediation system for soil, if required, are located on the main JPL campus in previously disturbed and developed areas, which contain no wetlands and provide minimal wildlife habitat. Therefore, certain location-specific ARARs (e.g., the Native American Graves Protection and

Repatriation Act, the Endangered Species Act, Section 404 of the Clean Water Act, and various provisions of the California Fish & Game Code) that might normally be an ARAR of consideration in an FS have been determined to be non-ARARs for this FS.

2.3.3 Potential Action-Specific ARARs

Action-specific ARARs are usually technology- or activity-based requirements for remedial activities. Action-specific ARARs described in this section are intended to address those actions resulting from implementation of remedial alternatives. Remedial alternatives for JPL could include the construction and operation of vapor extraction and treatment facilities and pipelines and other conveyance facilities needed to recover soil vapors from wells in various locations. A summary of potential action-specific ARARs, including a brief description, regulatory citation, and a determination as to “applicability” or “relevance and appropriateness” to the proposed remedial action is provided in Table 2-3. Brief descriptions of potential action-specific ARARs are also presented in the following subsections.

2.3.3.1 Clean Air Act - Local Air Quality Management

The primary treatment technology to be evaluated for addressing VOCs in soil vapor is carbon adsorption. Air emissions from vapor treatment units are regulated by the California Air Resources Board, which implements the federal Clean Air Act (CAA), as well as the air pollution control requirements of the California Health and Safety Code, which includes the state’s counterpart to the Clean Air Act, through local air quality management districts. Local districts may impose additional regulations to address local air emission concerns. The local air district for JPL is the South Coast Air Quality Management District (SCAQMD). The SCAQMD has adopted several rules that may be ARARs for air emissions.

SCAQMD Regulation XIII, comprising Rules 1301 through 1313, establishes new source review requirements. Rule 1303 requires that all new sources of air pollution in the district use best available control technology (BACT) and meet appropriate offset requirements. Emissions offsets are required for all new sources that emit in excess of one pound per day.

SCAQMD Rule 1401 requires that best available control technology for toxics (T-BACT) be employed for new stationary operating equipment, so that the cumulative carcinogenic impact from air toxics does not exceed the maximum individual cancer risk limit of 10 in 1 million (1×10^{-5}). Contaminants such as carbon tetrachloride and trichloroethene found in the JPL soil vapor are air toxics subject to Rule 1401.

SCAQMD Rules 401, 402, and 403 may also be ARARs for NASA depending on the remedy selected. Rule 401 limits visible emissions from a point source. Rule 402 prohibits discharge of material that is odorous or causes injury, nuisance, or annoyance to the public. Rule 403 limits downwind particulate concentrations.

These regulations may be applicable if the selected remedy involves air emissions from a soil vapor treatment system. It is noted that an SCAQMD permit was applied for and received for the soil-vapor extraction pilot system currently in operation at JPL.

2.3.3.2 Resource Conservation and Recovery Act and the California Hazardous Waste Management Program

The federal Resource Conservation and Recovery Act (RCRA) establishes requirements for the management and disposal of hazardous wastes. In lieu of the Federal RCRA program, the State of California is authorized to enforce its Hazardous Waste Control Act, and implementing regulations (California Code of Regulations (CCR) Title 22, Division 4.5), subject to the authority retained by EPA in accordance with the Hazardous and Solid Waste Amendments of 1984 (HSWA). California is responsible for permitting hazardous waste treatment, storage, and disposal facilities within its borders and carrying out other aspects of the RCRA program. Some of the Title 22 regulations may be ARARs if the selected remedy for JPL results in the generation, storage, treatment, or disposal of hazardous wastes.

2.4 IDENTIFICATION OF GUIDANCE AND CRITERIA TO BE CONSIDERED

Other standards, criteria, or guidance to be considered are federal, state, or local advisories or guidance that do not have the status of potential ARARs. If there are no specific federal or state ARARs for a particular chemical or remedial action, or if the existing ARARs are not considered sufficiently protective, then guidance or advisory criteria may be identified and used to ensure the protection of public health and the environment. TBCs may provide health effects information, technical information on performing or evaluating site investigations or remedial actions, and useful policies for dealing with hazardous substances.

2.4.1 Federal Guidance Documents

Many of the procedures and standards to be used in a CERCLA action are set forth in guidance documents issued by EPA. A list of the types of guidance that are TBC is included in the preamble to the NCP, 55 Federal Register 8765 (March 8, 1990). That guidance, along with current updates of and additions to that guidance, will be considered in this FS and in selecting and implementing the remedy at JPL.

2.4.2 Chemical-Specific TBCs

The following chemical-specific TBCs shall be considered in the evaluation of the potential remedial alternatives.

2.4.2.1 Preliminary Remediation Goals

EPA Region IX has created a set of preliminary remediation goals (PRGs) for a number of organic and inorganic constituents for both industrial and residential site-use scenarios. The PRGs consider a number of exposure pathways. The PRG values are often proposed as

cleanup goals by federal, state and local agencies for responsible parties as an alternative to performing a risk-assessment. PRGs for the JPL soil contaminants have been developed. PRGs may be considered in determining soil cleanup goals for JPL.

2.4.2.2 U.S. EPA Soil Screening Levels

EPA's soil screening guidance document (EPA, 1996) proposes soil screening levels (SSLs) that are to be evaluated in consideration of potential migration of contaminants to underlying potable aquifers. The SSL values are often proposed as cleanup goals by federal, state and local agencies for responsible parties as an alternative to performing a risk-assessment. Generic SSLs for the protection of groundwater are derived using default values in standardized equations presented in the guidance document (EPA, 1996).

According to EPA (1996) guidance, the SSLs were developed using a default dilution-attenuation factor (DAF) of 20 to account for natural processes that reduce contaminant concentrations in the subsurface. Generic SSLs assume no dilution or attenuation between the source and the receptor well (i.e., a DAF of 1). These values can be used at sites where little or no dilution or attenuation of soil leachate concentrations is expected at a site (e.g., sites with shallow water tables, fractured media, karst topography, or source size greater than 30 acres). SSLs for the JPL soil contaminants have been developed and may be considered in determining soil cleanup goals for JPL. However, in general, if an SSL is not exceeded for the migration to groundwater pathway, this pathway may be eliminated from further investigation.

2.4.2.3 RWQCB Interim Site Assessment and Cleanup Guidebook

The California Regional Water Quality Control Board, Los Angeles Region (RWQCB) published their *Interim Site Assessment and Cleanup Guidebook* in May of 1996. The purpose of the guidebook was to present a new approach to the cleanup process: one that reduced time, cut costs, and established a defined endpoint for investigations and cleanup actions. Chapter 5.0 of the guidebook presents soil-screening levels for VOCs in the vadose zone, which are calculated from attenuation factors derived from equations based on chemical and physical parameters. This approach can be used to generate soil-screening levels (SSLs), and is a potential means of evaluating adequate cleanup of soils at JPL. However, at JPL, it has been generally agreed that soil vapor concentrations would be used for determining the nature and extent of contamination. Hence, in order to compare with SSLs, the soil vapor concentrations would have to be converted to a soil concentration. This will be further evaluated prior to finalizing the design for full-scale implementation.

2.4.3 Action-Specific TBCs

The following action-specific TBCs shall be considered in the evaluation of the potential remedial alternatives.

2.4.3.1 RWQCB Interim Site Assessment and Cleanup Guidebook

The RWQCB published their *Interim Site Assessment and Cleanup Guidebook* in May of 1996. Chapter 5.0 presents performance standards for vapor extraction systems. The performance standards from the *Interim Site Assessment and Cleanup Guidebook* for soil vapor extraction systems shall be considered if the remedial alternative at JPL involves soil vapor extraction.

2.4.3.2 RWQCB Interim Guidance for Active Soil Gas Investigation

In February 1997, the RWQCB published their latest *Interim Guidance for Active Soil Gas Investigations*, which updates a previous RWQCB (1992) soil gas guidance. The latest guidance document presents the RWQCB preferred procedures and techniques for soil gas investigation survey design, sample collection, analysis, and reporting. The guidance shall be considered if soil gas sampling and analysis is planned for JPL as part of the remedial alternative.

TABLES

TABLE 2-1
POTENTIAL CHEMICAL-SPECIFIC ARARs
JET PROPULSION LABORATORY

Requirement	Prerequisites	Citation	ARAR Determination	Comments
U.S. EPA				
Maximum contaminant levels for drinking water.	Remediation	Safe Drinking Water Act (40 CFR, Part 141)	Relevant and Appropriate	Soil will be remediated to a level expected to protect groundwater quality.
Preliminary Remediation Goals (PRGs) provide a risk-based criteria for evaluating soil contamination and cleanup actions.	Remediation	U.S. EPA Region IX Guidance	To be considered (TBC)	Soil will be remediated to a level expected to protect groundwater quality.
Soil Screening Levels (SSLs) used to provide a risk-based criteria for screening soil contamination.	Soil Remediation	U.S. EPA Soil Screening Guidance	To be considered (TBC)	Soil will be remediated to a level expected to protect groundwater quality.
California Department of Health Services				
Maximum contaminant levels for drinking water.	Remediation	California Safe Drinking Water Act (California Health and Safety Code, Division 5, Part 1, Chapter 7)	Relevant and Appropriate	Soil will be remediated to a level expected to protect groundwater quality.
State and Regional Water Quality Control Board (RWQCB)*				
Standards for corrective action of waste management units	Remediation	Title 23, CCR, Division 3, Chapter 15, Article 5, Section 2550	Applicable	Substantive provisions are ARARs.
Incorporated into all Regional Board Basin Plans. Requires that quality of waters of the state that is better than needed to protect all beneficial uses be maintained unless certain findings are made. Discharges to high quality waters must be treated using best practicable treatment or control necessary to prevent pollution or nuisance and to maintain the highest quality water. Requires cleanup to background water quality or to lowest concentrations technically and economically feasible to achieve. Beneficial uses must, at least, be protected.	Waters of the state	SWRCB Resolution No. 68-16 (Policy with Respect to Maintaining High Quality of Waters in California) (Water Code Section 13140, Clean Water Act 40 CFR, Part 131.12)	Relevant and Appropriate	Soil will be remediated to a level expected to protect groundwater quality.
Establishes policies and procedures for the oversight of investigations and cleanup and abatement activities resulting from discharges of waste that affect or threaten water quality. It authorizes the Regional Water Boards to require cleanup of all waste discharged and restoration of affected water to background conditions. Requires actions for cleanup and abatement to conform to Resolution 68-16 and applicable provisions of Title 23 CCR, Division 3, Chapter 15 as feasible.	Remediation affecting water.	SWRCB Resolution 92-49 (Policies and Procedures for Investigation and Cleanup and Abatement of Discharges Under Water Code Section 13304) (Water Code Section 13307)	Relevant and Appropriate	Soil will be remediated to a level expected to protect groundwater quality.
Describes the water basins in Los Angeles River Basin region, establishes beneficial uses of ground and surface waters, establishes water quality objectives, including narrative and numerical standards, establishes implementation plans to meet water quality objectives and protect beneficial uses, and incorporates statewide water quality control plans and policies.	Remediation affecting water.	Water Quality Control Plan for the Los Angeles River Basin (Water Code 13240)	Potentially applicable	Soil will be remediated to a level expected to protect groundwater quality.
Approach for investigation and cleanup of soil in the Los Angeles River Basin.	Remediation	RWQCB Interim Site Assessment and Cleanup Guidebook	To be considered (TBC)	Soil will be remediated to a level expected to protect groundwater quality.

* Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate that NASA accepts the entire statutes or policies as potential ARARs. Specific potential ARARs are addressed in the table below each general heading; only substantive requirements of specific citations are considered potential ARARs.

- ARAR - Applicable or relevant and appropriate requirements.
- CCC - California Coastal Commission.
- CCR - California Code of Regulations.
- CFR - Code of Federal Regulations.
- RWQCB - California Regional Water Quality Control Board.
- SSL - Soil Screening Level
- USC - United States Code.

TABLE 2-2
POTENTIAL LOCATION-SPECIFIC ARARs
JET PROPULSION LABORATORY

Location	Requirement	Prerequisites	Citation	ARAR Determination	Comments
Federal Facilities Compliance Act^a					
Federal Facility	Facility must comply with federal, state, and local requirements concerning waste management.	Waste management	42 USC, Section 6901	Applicable	The facility will comply with federal, state, and local requirements concerning waste management.
Executive Order 11988, Protection of Floodplains^a					
Within floodplain	Actions taken should avoid adverse effects, minimize potential harm, and restore and preserve natural and beneficial resources.	Action that will occur in a floodplain (i.e., lowlands) and relatively flat areas adjoining inland and coastal waters and other flood-prone areas	40 CFR 6, Appendix A (excluding Sections 6[a][2], [4], and [6]); 40 CFR, Part 6.302	Applicable	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus and outside of the 100-year floodplain of Arroyo Creek.
Archaeological Resources Protection Act, 16 USC Section 469 at seq^a					
Within area where action may cause irreparable harm, loss, or destruction of significant artifacts	Construction on previously undisturbed land would require an archaeological survey of the area.	Alteration of terrain that threatens significant scientific, prehistoric, historic, or archaeological data	36 CFR, Part 65	Potentially Applicable	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus. However, a historic, archaeological, architectural, and cultural resource review of surrounding and on-site property will be conducted prior to implementation of remedial actions involving structure demolition, construction, or intrusive groundwork.
National Historic Preservation Act, 16 USC Section 470^a					
Historic project owned or controlled by Federal agency	Action to preserve historic properties; planning of action to minimize harm to national historic landmarks.	Property included in or eligible for the National Register of Historic Places	36 CFR, Part 800	Potentially Applicable	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus, but no buildings or structures are likely to be impacted by system installation or operation. However, a historic, archaeological, architectural, and cultural resource review of surrounding and on-site property will be conducted prior to implementation of remedial actions involving structure demolition, construction, or intrusive groundwork.
Native American Graves Protection and Repatriation Act of 1990					
Within area where Native American human remains, funerary objects, sacred objects, or objects of cultural patrimony are found.	Provides requirements for the identification and appropriate disposition of human remains, funerary objects, sacred objects, or objects of cultural patrimony.		43 CFR, Part 10	Not an ARAR	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus. Therefore, human remains, funerary objects, sacred objects, or objects of cultural patrimony are not expected. If found, however, the substantive provisions of this law will be followed.
Endangered Species Act of 1973^a					
Critical habitat upon which endangered species or threatened species depend	Action to conserve endangered species or threatened species, including consultation with the Department of the Interior.	Determination of effect upon endangered or threatened species or their habitat	16 USC 1536(a)	Not an ARAR	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus.
Executive Order 11990, Protection of Wetlands^a					
Wetland	Action to minimize the destruction, loss, or degradation of wetlands.	Wetland as defined by Executive Order 11990, Section 7	40 CFR, Part 6,	Not an ARAR	Areas identified for soil remediation system component installation are located on previously disturbed and

TABLE 2-2
POTENTIAL LOCATION-SPECIFIC ARARs
JET PROPULSION LABORATORY

Location	Requirement	Prerequisites	Citation	ARAR Determination	Comments
					developed areas of the JPL campus and outside the area of any potential wetlands.
Clean Water Act, Section 404^a					
Wetland	Action to prohibit discharge of dredged or fill material into wetland without permit. Mitigation may be required to avoid net loss of wetlands.	Wetland as defined by Executive Order 11990, Section 7	40 CFR, Part 230.10	Not an ARAR	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus and outside the area of any potential wetlands.
Fish and Game Code^a					
Wildlife Species/Habitats	Action must be taken for the general protection and conservation of fish and wildlife resources.		Fish & Game Code Section 1600	Not an ARAR	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus.
Wetlands	Actions must be taken to assure that there is "no net loss" of wetlands acreage or habitat value. Action must be taken to preserve, protect, restore, and enhance California's wetland acreage and habitat values.		Fish and Game Commission Wetlands Policy (adopted 1987) included in Fish and Game Code Addenda	Not an ARAR	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus.
Rare native plants	Action must be taken to conserve native plants; there can be no releases and/or actions that would have a deleterious effect on species or habitat.		Fish & Game Code Sections 2080 and 1900 <i>et seq</i>	Not an ARAR	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus.
Endangered Species Habitat	No person shall import, export, take, possess, or sell any endangered or threatened species or part or product thereof	Threatened or endangered species determination on or before 1 January 1985 or a candidate species with proper notification	Fish and Game Code Section 2080	Not an ARAR	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus.
Endangered Species Habitat	Department policy and legislative findings and definitions for significant natural areas		Fish and Game Code Sections 2050-2068	Not an ARAR	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus.
Endangered Species Habitat	Procedures for listing endangered species		Fish and Game Code Section 2070	Not an ARAR	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus.
Endangered Species Habitat	Ensures that action taken will not jeopardize the survival and reproduction of any threatened or endangered species		Fish and Game Code Sections 2090-2096	Not an ARAR	Areas identified for soil remediation system component installation are located on previously disturbed and developed areas of the JPL campus.

^a Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate that NASA accepts the entire statutes or policies as potential ARARs. Specific potential ARARs are addressed in the table below each general heading; only substantive requirements of specific citations are considered potential ARARs.

ARAR - Applicable or relevant and appropriate requirements.
CCC - California Coastal Commission.
CCR - California Code of Regulations.
CFR - Code of Federal Regulations.
RWQCB - California Regional Water Quality Control Board.
USC - United States Code.

TABLE 2-3
POTENTIAL ACTION-SPECIFIC ARARs
JET PROPULSION LABORATORY

Action	Requirement	Prerequisites	Citation	ARAR Determination	Comments
Clean Air Act (CAA) 40 USC 7401 et seq.					
Discharge to air	Provisions of State Implementation Plan (SIP) approved by EPA under Section 110 of CAA.	Major sources of air pollutants	40 USC, Section 7410; portions of 40 CFR, Part 52.220, applicable to South Coast Quality Management District	Applicable	Appropriate protocols will be followed.
	National Primary and Secondary Ambient Air Quality Standards (NAAQS) - standards for ambient air quality to protect public health and welfare.	Contamination of air affecting public health and welfare	40 CFR, Parts 50.4 - 50.12	Applicable	Appropriate protocols will be followed.
South Coast Air Quality Management District (SCAQMD)					
Discharge of air emissions	Requires a permit to construct for equipment causing the issuance of air contaminants.	Sources of air pollutants	SCAQMD Regulation II, Rule 201	Applicable	Equipment used for the removal action will meet the appropriate permit requirements.
	Requires a permit to operate for equipment causing the issuance of air contaminants.	Sources of air pollutants	SCAQMD Regulation II, Rule 203	Applicable	Equipment used for the removal action will meet the appropriate permit requirements.
	Limits visible emissions from any point source.	Visible emission to atmosphere.	SCAQMD Regulation IV, Rule 401	Applicable	Air emissions will be controlled.
	Prohibits the discharge of any air emissions in quantities that may cause injury, detriment, nuisance, or annoyance to the public.		SCAQMD Regulation IV, Rule 402	Applicable	Air emissions will be controlled.
Discharge of fugitive dust	Limits onsite activities so that the concentrations of fugitive dust at the property line shall not be visible and the downwind particulate concentration shall not be more than 100 micrograms per cubic meter, averaged over 5 hours, above the upwind particulate concentration. This rule also requires every reasonable precaution to minimize fugitive dust and the prevention and cleanup of any material accidentally deposited on paved streets.	Sources of fugitive dust	SCAQMD Regulation IV, Rule 403	Applicable	Dust generated during removal actions will be controlled
Resource Conservation and Recovery Act					
Hazardous waste generation, management, and disposal	Sets requirements for generators of hazardous waste concerning management, treatment, storage, and disposal. Authorizes California to enforce their own hazardous waste program under the California Hazardous Waste Control Act.	Generation of hazardous waste	40 CFR, Part 260 – 280 and 22 CCR, Sections 66260 – 66280.	Applicable	Implementation of the proposed remedy is not anticipated to generate significant amounts of hazardous waste.
Regional Water Quality Control Board					
Soil Remediation	Presents performance standards for vapor extraction systems.	Vapor extraction and treatment	RWQCB Interim Site Assessment and Cleanup Guidebook	To be considered (TBC)	Appropriate protocols will be followed.
Soil Gas Sampling	Presents procedures and techniques for soil gas investigation survey design, sample collection, analysis, and reporting.	Soil gas investigation	RWQCB Interim Guidance for Active Soil Gas Investigations	To be considered (TBC)	Appropriate protocols will be followed.

*Statutes and policies, and their citations, are provided as headings to identify general categories of potential ARARs. Specific potential ARARs are addressed in the table below each general heading.

ARAR	- Applicable or relevant and appropriate requirement.	RWQCB	- California Regional Water Quality Control Board, Los Angeles Region.
CAA	- Clean Air Act	SCAQMD	- South Coast Air Quality Management District
CCR	- California Code of Regulations.	SWRCB	- California State Water Resources Control Board.
CFR	- Code of Federal Regulations.	SDWA	- Safe Drinking Water Act.
EPA	- U.S. Environmental Protection Agency.	SIP	- State Implementation Plan.
NAAQS	- National Ambient Air Quality Standards (primary and secondary).	TBC	- To be considered.
NESHAPs	- National emission standards for hazardous air pollutants.	USC	- United States Code.
RCRA	- Resource Conservation and Recovery Act.		

3.0 IDENTIFICATION, SCREENING, AND EVALUATION OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

The primary purpose of this FS is to develop and analyze remedial alternatives to address JPL-impacted soil in the vadose zone. In this section, treatment technologies and process options that are applicable to the vadose zone contamination are identified and evaluated against EPA criteria. This process is intended to provide the background for Section 4.0 of this report where comprehensive remedial alternatives are developed. These alternatives are evaluated with regard to implementation, effectiveness, and cost, and those that pass the screening in Section 4.0 are evaluated in detail in Section 5.0.

3.1 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

Remedial action objectives (RAOs) consist of goals for protecting human health and the environment for a particular medium. In this case, the soil in the vadose zone at JPL is the medium. When developing RAOs, the nature and extent of contamination, probable contaminant migration patterns, potential exposure pathways, and remediation goals defining acceptable contaminant levels are taken into consideration. In addition, EPA guidance requires consideration of a "No Action" alternative to provide a baseline against which other alternatives can be compared.

RAOs are generally focused on protecting human health and the environment by identifying ways to decrease contaminant concentrations and/or eliminate pathways to potential receptors. Results of the risk assessment for OU-2 indicated that surface soils at JPL do not pose a risk to human health or to environmental receptors (Foster Wheeler, 1999b), and, therefore, no action is required to address surface soils in the FS (see to Section 1.3.9.1). Thus, the focus of this FS is to protect the groundwater beneath the site.

3.1.1 Groundwater Quality at JPL

On-site and off-site groundwater is the subject of the OU-1/OU-3 RI report, (Foster Wheeler, 1999a). It was determined in this study that VOCs are present in the groundwater at concentrations in excess of regulatory standards, and that this contamination originated from the vadose zone. A brief discussion of groundwater quality beneath the JPL area is provided below.

Groundwater samples collected from the JPL study area were analyzed for a comprehensive suite of analytes including 60 VOCs, 65 SVOCs, 19 metals (excluding cations), perchlorate (ClO_4^-), cyanide (CN), tributyltin (TBT), total petroleum hydrocarbons (TPH), gross alpha/gross beta and general groundwater parameters (major anions and cations). Of these analyses, only three VOCs [carbon tetrachloride (CCl_4), trichloroethene (TCE), and 1,2-dichloroethane (1,2-DCA)], one metal [total chromium (Cr)], and ClO_4^- were detected on-site at levels exceeding state and federal maximum contaminant levels (MCLs) or interim action levels (IALs) during the OU-

1/OU-3 RI period. Hexavalent chromium [Cr(VI)] was also detected; however, MCLs have not been established for Cr(VI). It is noted that ClO_4^- was detected in the late stages of the OU-1/OU-3 RI, after the OU-2 field work was completed (see Section 1.3.7.2).

CCl_4 appears to have originated on-site and migrated downward and eastward. The resulting plume extends off-site to the east where it has apparently been kept from significant further downgradient migration primarily by the effects of pumping at the Pasadena municipal wells. TCE and ClO_4^- appear to have both on-site and off-site sources. Plumes of these contaminants have also migrated downgradient (eastward) into the vicinity of the Pasadena and Lincoln Avenue Water Company (Lincoln) production wells, where they too appear to have been contained from further significant downgradient migration. 1,2-DCA was only observed in on-site JPL wells and was not detected at any of the off-site monitoring wells during the RI.

Data indicate that VOC and ClO_4^- plume concentrations exceeding respective MCLs or IALs are generally found in monitoring wells located on-site and to the east around the Pasadena and Lincoln Avenue municipal production wells. Overall, VOC concentrations in JPL monitoring wells located within the plumes have generally remained relatively consistent over the course of the RI period. The general lack of significant contaminant plumes east of the Pasadena and Lincoln Avenue municipal wells suggests that these production wells provide a barrier to further significant downgradient migration.

Chromium, both total and hexavalent [Cr(VI)], were detected frequently in several on-site wells and extremely rarely in scattered off-site monitoring wells, mostly at levels well below MCLs [no MCLs have been established for Cr(VI)]. Where Cr [total and Cr(VI)] was detected in on-site wells, concentrations decreased or remained relatively constant during the RI period. These detections are isolated, and there is no evidence of a Cr plume.

In light of the groundwater RI, the issues regarding groundwater remediation are focused on VOCs and ClO_4^- .

3.1.2 Factors used to Develop RAOs

The JPL vadose zone constituents of interest, exposure pathways, and remediation goals that will be used to develop the RAOs are discussed in the following subsections.

3.1.2.1 Constituents of Interest in JPL Soils

During the OU-2 RI, soil samples were collected from 37 locations at depths ranging from 1 to 101 feet bgs. Soil vapor samples were collected from 63 locations at depths ranging from 6 to 205 feet bgs. Results from analysis of soil samples showed low concentrations of metals, which were generally consistent with background levels. A few other samples (mostly collected near the surface) were also found to contain small amounts of various organic compounds. Results from the soil-vapor investigation revealed VOCs in the vadose zone at depths ranging from about 20 feet to groundwater (more than 200 feet) with concentrations and detection frequency generally

increasing with increasing depth. As noted in Section 3.1, no risk to human health or to environmental receptors was identified for OU-2 contaminants in surface soils (Foster Wheeler, 1999b), and the focus of this FS is removal of VOCs from the vadose zone to inhibit their potential migration to groundwater. Compounds detected in soil and soil-vapor samples are discussed below, along with the rationale for inclusion or exclusion as constituents of interest in this FS.

Volatile Organic Compounds

Although VOC concentrations in groundwater are not increasing, VOCs in the vadose zone are of potential concern because they were detected at depths ranging from about 20 feet to more than 200 feet (extending to the water table), and, thus, have the potential to impact groundwater quality. The OU-2 RI showed that four VOCs were consistently present in JPL soil-vapor samples, including:

- Carbon tetrachloride (CCl₄)
- 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113)
- Trichloroethene (TCE)
- 1,1-Dichloroethene (1,1-DCE).

Of these, the most prevalent is CCl₄, followed by Freon 113, TCE, and 1,1-DCE. These four compounds are identified as constituents of interest for the JPL OU-2 FS. It is noted that other VOCs were detected during the RI; however, these detects were sporadic and concentrations were very low relative to the four primary compounds. Therefore, they are of minimal interest.

Other Organic Compounds

During the RI, soil samples were analyzed for TPH, SVOCs, PAHs, PCBs, dioxins, and tributyltin. Analytical results indicated that several of these compounds were present, but were detected with very low frequency. In addition, where detected in the upper 15 feet, these compounds were determined to be of negligible risk in the OU-2 risk assessment (see Section 1.3.9.1). These compounds were detected mainly in near-surface soils, and downward migration has not occurred to a significant degree. It is considered unlikely that significant downward migration will occur in the future. This is based on data showing that many years after releases occurred, only TPH and two SVOCs were detected in soil at depths greater than 10 feet. This is further supported by the observation that these compounds have not impacted groundwater beneath the site (Foster Wheeler, 1999a).

It is noted that n-nitroso-di-N-propylamine and total petroleum hydrocarbons (TPH) were detected in soil samples at concentrations exceeding preliminary regulatory goals/recommendations. Since these compounds were detected in soil samples collected from below the depths for which risk was evaluated, they were not included in the risk assessment (see Section 1.3.9.1), and an explanation for not proposing remedial actions for these compounds

is in order. The compound n-nitroso-di-N-propylamine was detected only once (soil boring No. 30) during the entire RI, at a concentration of 0.5 mg/kg, at depth of 30 feet bgs. This compound is very soluble (solubility is 9.9 g/L) and moderately adsorbing to soil solids (log K_{ow} is 1.31), and, therefore, could be considered somewhat mobile (Foster Wheeler, 1999b). Despite this, n-nitroso-di-N-propylamine was not detected at greater depths in the soil immediately beneath the positive sample (soil samples were collected from soil boring No. 30 at additional depths of 40, 50, and 65 feet bgs). In addition, n-nitroso-di-N-propylamine was not detected in groundwater during the OU-1/OU-3 RI.

TPH was detected at a concentration of 6500 mg/kg in soil boring No.1 at a depth of 20 feet bgs. As mentioned in Section 1.3.7.2, this was due to tiny asphalt granules in backfill materials, and all other TPH detects were at least one order of magnitude lower, and most were two or more orders of magnitude lower. A sample collected from soil boring No.1 at a depth of 37 feet bgs contained TPH at 11 mg/L, and TPH compounds are not of importance regarding the groundwater RI/FS at JPL (Foster Wheeler, 1999a).

Based on this information, no other organic compounds in the vadose zone pose a significant threat to groundwater quality and are not considered to be of interest with regard to the FS for OU-2.

Inorganic Constituents

Soil samples were analyzed for a number of inorganic constituents, including various metals, cyanide (CN^-), and nitrate (NO_3^-). Metal concentrations were determined to be generally consistent with background levels and with published naturally-occurring levels in California soils (Foster Wheeler, 1999b). Therefore, they are not considered to be of interest for the FS. Cr(VI), which is generally not considered to occur naturally in soils, was detected in one soil boring and three test pits, CN^- was detected in one soil boring only, and NO_3^- was detected in most of the soil borings at JPL. As presented in the OU-2 RI report (Foster Wheeler, 1999b), these compounds posed negligible risk to human and other ecological receptors, and their potential for impacting groundwater is very low. Therefore, these constituents are not considered to be of interest with regard to this FS.

3.1.2.2 Exposure Pathways

As discussed in the risk assessment for OU-2 (Foster Wheeler, 1999b) and summarized in Section 1.3.9.1, exposure to surface soils at JPL poses no significant risk to human receptors. Furthermore, there are no direct exposure pathways to contaminated soil at depths greater than 15 feet at JPL. Because the VOCs identified as constituents of interest for the FS are present at depths greater than 20 feet, there are no direct exposure pathways for this contamination. It is noted that migration of VOC vapor from soil has impacted groundwater beneath the site, and the need to minimize further migration is acknowledged. However, potential exposure to contaminants via groundwater is the subject of the OU1/OU-3 RI/FS.

3.1.2.3 Preliminary Remediation Goals

The preliminary remediation goals (PRGs) are target treatment levels for the medium of interest, in this case vadose-zone soils. These generally involve protection of human receptors from unacceptable contaminant levels in the medium of interest. However, as noted above, no direct risks, or pathways for exposure to contaminated vadose zone soils were identified for human receptors. Therefore, the focus of this FS has been shifted to protecting groundwater beneath the site. Hence, PRGs are defined for this FS as vadose zone VOC concentrations required to protect groundwater from further migration of VOCs. These will be determined based on RWQCB protocol as discussed in Appendix C.

3.1.2.4 Site Conceptual Model/Summary of Relevant Issues

The above information on constituents of interest and exposure pathways, along with various information presented in Section 1.0, was used to develop a site conceptual model (SCM) for OU-2. This is shown on Figure 3-1. It should be noted that Figure 3-1 is a schematic representation of the site and is provided for illustration only. Following is a summary of relevant issues in OU-2 that form the basis of the SCM.

- Soils at the site are primarily medium- to coarse-grained sands and gravel with occasional fine-grained intervals of silt and silty sand.
- Contaminants were discharged to waste disposal areas in OU-2 over 30 years ago.
- Along with chemical wastes, large amounts of water were discharged to the waste disposal areas as the pits accepted liquid and solid sanitary wastes collected from drains and sinks within the buildings.
- The introduction of large amounts of water served to flush mobile contaminants into the deeper portions of the vadose zone and into the groundwater. Soil and groundwater data have confirmed this since VOCs, which are relatively soluble and mobile in JPL soils, are generally found deep in the vadose zone and have impacted groundwater beneath the site. Conversely, other organic compounds detected at the site, which are generally characterized by lower solubilities and higher affinities for adsorption by soil, were detected in shallow portions of the vadose zone. These compounds were not detected in groundwater, or detections were infrequent, sporadic, and concentrations were below regulatory limits.
- A human health risk assessment was conducted to assess risks associated with surface soils at JPL. Results indicated that risks associated with direct exposure to soils at JPL were negligible and no remedial action was required. However, the OU-1/OU-3 RI confirmed that VOCs have migrated from the soil to the groundwater and remedial action is, therefore, required for VOCs to protect a drinking water source.
- The most frequently detected VOCs in vadose zone soil-vapor at JPL include CCl₄, Freon 113, TCE, and 1,1-DCE. These four compounds are identified as constituents of interest for the OU-2 FS. Soil-vapor data from the RI suggest that these compounds form a co-mingled VOC plume located in central portion of the site. The plume

encompasses approximately 45 acres, and ranges in depth from approximately 50 feet bgs to the water table (averaging approximately 170 feet bgs).

3.1.3 Remedial Action Objectives

Based on the above information regarding constituents of interest, exposure pathways, and PRGs, RAOs for the site were developed. This process was simplified by the fact that OU-2 includes only one medium of concern (soil) and only one environmental concern—the migration of VOCs from the vadose zone to the groundwater. Development of RAOs to protect human health regarding direct exposure to soils is not needed since it was determined in the risk assessment that the vadose zone soils do not pose risks to humans.

Therefore, the appropriate RAO for OU-2 is to prevent, to the extent possible, migration of VOCs to groundwater (under RWQCB's non-degradation policy) to protect an existing drinking water source.

3.2 ESTIMATED MASS OF CONTAMINANTS AND VOLUME OF CONTAMINATED SOIL

The mass of contaminants and volume of contaminated soil in the subsurface for OU-2 was estimated for TCE, DCE, CCl₄, and Freon 113. Two different methods were used in the calculations.

Method 1 used the VOC data presented in Section 4.0 in terms of contours representing the areal distribution of contamination, and soil-vapor concentration data for each of the target compounds. First, the total volume of soil contaminated with the particular constituent was estimated. Next, the pore volume (soil-vapor volume) was calculated using the soil porosity. Finally, the mass of contaminant was determined by multiplying the average concentration in soil vapor by the pore volume of the soil.

Method 2 utilized the same soil characterization data, but involved a more rigorous calculation of the soil concentration. The total soil concentration in the soil was calculated from the soil vapor data presented in Section 4.0 using soil physical parameters for the site and chemical properties for each particular constituent. The total soil concentration was then multiplied by the total volume of the soil estimated from Method 1 to obtain VOC mass.

Method 1

The following procedure was followed to calculate the mass of contaminant:

- The areal extent of contamination for the four target VOCs was estimated from Figures 1-15, 1-17, 1-19, and 1-21. The outermost contour, representing the maximum distribution of contamination for the sampling events, was considered.
- The average depth of soil was assumed to be 200 feet (ft).

- The total volume of contaminated soil was calculated by multiplying the area of contamination by the depth of the soil.

$$\text{Volume Soil (ft}^3\text{)} = \text{Area (ft}^2\text{)} \times \text{Depth (ft)} \quad (1)$$

- The pore volume of soil was calculated by multiplying the estimated soil porosity of 0.35 by the volume of soil from (1). Soil porosity was estimated based on the soil type.

$$\text{Pore Volume} = \text{Volume Soil} \times \text{Porosity} \quad (2)$$

- The soil-vapor concentration for each contaminant was estimated by taking one-half the maximum value reported for Event 6 (Figures 1-15, 1-17, 1-19, and 1-21). These values were reported in units of $\mu\text{g/L}$ in the RI Report.
- The soil-vapor concentration in $\mu\text{g/L}$ was converted into units of lb/ft^3 by multiplying with several conversion factors for mass and volume.

$$C = C_g \times 28.3 \text{ L/ft}^3 \times 10^{-9} \text{ kg/}\mu\text{g} \times 2.205 \text{ lb/kg} \quad (3)$$

Where:

C_g = Soil-vapor concentration ($\mu\text{g/L}$)

C = Soil-vapor concentration (lb/ft^3)

- Finally, the mass of each contaminant in the soil was calculated. The soil-vapor concentration from (3) was multiplied by the pore volume of soil calculated in (2).

Method 2

- The total vapor concentration in soil was calculated from an equation presented in the RWQCB (1996) guidebook.

The equation reads as follows:

$$C_T = C_g \times \{ \theta_w + [(n - \theta_w) \times K_H] + (\rho_b \times f_{oc} \times K_{oc}) \} / (\rho_b \times K_H) \quad (3)$$

Where:

C_T = Total soil concentration ($\mu\text{g/kg}$)

C_g = Soil-vapor concentration ($\mu\text{g/L}$)

θ_w = Soil water content by volume

n = Soil porosity

K_H = Henry's law constant

ρ_b = Soil bulk density (g/cc)

f_{oc} = Soil organic carbon content

K_{oc} = Organic carbon partition coefficient (mL/g)

- C_g data was interpreted in the same manner as in Method 1.
- Chemical parameters for the VOCs [i.e., Henry's law constant and organic carbon partition coefficient, were taken from Appendix A, Table 2, in the RWQCB (1996) guidebook].
- Soil physical parameter data [i.e., soil bulk density, soil water content, soil organic carbon content, and soil porosity, were taken from Appendix A, Table 1, in the RWQCB (1996) guidebook] were based on the soil type.
- The VOC mass in the soil was calculated by multiplying the result of (3) with the total volume of soil derived in (1), the soil bulk density, and various conversion factors:

$$M = C_T \times \text{Volume Soil (ft}^3\text{)} \times \rho_b \text{ (g/cc)} \times 62.43 \left(\frac{\text{lb/ft}^3}{\text{g/cc}} \right) \times 10^{-9} \quad (4)$$

Where:

M = Mass of VOC compound in soil (lb)

The estimated volumes of contaminated soil for all four contaminants are listed in Table 3-1. Presented in Tables 3-1 and 3-2 are the values for the soil and contaminant parameters, including mass in the soil for all four contaminants, for Methods 1 and 2, respectively. As shown in Tables 3-1 and 3-2, the mass of contaminants by the two methods are approximately 2,251 and 5,038 pounds, respectively. The large disparity between the calculated masses is due to the difference inherent in the two methodologies used to calculate the approximate mass.

It should be noted that the significant changes in elevation at OU-2, combined with the fact there might be "clean" pockets of soil pores within the overall contaminant envelopes, make it difficult to accurately estimate the mass of contaminants present in the soils. The above methods are fairly simplistic in nature, and are intended to merely provide an idea of the "order of magnitude" of mass, rather than an actual estimate.

3.3 IDENTIFICATION OF APPROPRIATE REMEDIAL TECHNOLOGIES- PRESUMPTIVE REMEDY FOR VOCs IN SOIL

Vadose zone soils at the JPL site are impacted with VOC vapors that extend to the water table, and they have impacted the quality of the groundwater beneath the site. Based on the RAOs for the site, remedial activities may be conducted to reduce the mass of VOCs in the soil, thereby limiting migration to the aquifer beneath the site.

EPA guidance requires that the feasibility study process include identification and evaluation of technology types with respect to technical implementability, effectiveness, and cost (EPA, 1988a). Technologies that are incompatible with the nature and extent of contamination or the physical configuration of the site are eliminated from further consideration.

The EPA has developed a list of remedies that are presumed to be the most effective for sites with VOC contamination in soil. These presumptive remedies are:

- Soil Vapor Extraction (SVE)
- Excavation/Thermal Desorption
- Excavation/Incineration

This list is based on the EPA's collective knowledge about site investigation and remedy selection for VOC-contaminated soils. The EPA conducted an analysis of fiscal year (FY) 1986 to 1991 (FY86 to FY91) Records of Decision (RODs) for sites where VOCs in soil were the primary consideration in selecting a remedy. The results of this analysis showed that these three technologies represent over 90 percent of the remedies selected in the RODs analyzed. Therefore, one of these presumptive remedies is expected to be used for all VOC sites except under unusual circumstances (EPA, 1993b).

The presumptive remedy approach is used to accelerate the technology selection process within the Superfund Accelerated Cleanup Model (SACM). This is accomplished by eliminating the need to evaluate site specific options that are routinely screened out at VOC-contaminated sites based effectiveness, implementability and cost. JPL has elected to pursue the presumptive remedy approach for the following reasons:

- VOCs are the primary constituents of interest in the vadose zone soils at the site.
- There are no unusual circumstances at the site that would preclude use of the presumptive remedies.
- SVE has been successfully piloted at the site (see Appendix A).

3.3.1 Evaluation of Presumptive Remedies

Of the three presumptive remedies, SVE is the primary option. The historical data show that SVE has been selected most frequently to address VOC contamination at Superfund sites. Initial performance data indicate that SVE effectively treats waste in place at a relatively low cost. In cases where SVE is not feasible, or where contamination is very highly concentrated, excavation/thermal desorption may be considered. In a limited number of situations, excavation/incineration may be more appropriate (EPA, 1993b). In all cases, SVE is considered first, followed by excavation/thermal desorption, followed by excavation/incineration.

3.3.1.1 Soil Vapor Extraction

SVE can be applied either in situ or ex situ, and is being considered as an in situ process for this FS. In situ SVE is a process in which a vacuum is applied through extraction wells screened in the vadose zone. The vacuum creates a pressure gradient that induces gas-phase volatiles to diffuse through soil to the extraction wells where they are then drawn to the surface. Off-gas treatment is required for the extracted vapors. The number of extraction wells required to

adequately remediate the site depends on the radius of influence (ROI), which in turn depends on a number of site-specific parameters such as permeability of the soil, homogeneity of the soil, and presence of layers of lower permeability.

The degree of success of SVE at any site typically depends on the following four parameters:

- Soil type – the higher the permeability, the greater the potential for success. Sands and gravels are amenable, while silts and clays are not as amenable. For silts and clays, enhancements to SVE such as air injection, heat injection, or pneumatic fracturing may be required.
- Soil moisture content – the lower the soil moisture content, the greater the success.
- Soil organic content – the lower the soil organic carbon content, the greater the success.
- Contaminant volatility – the more volatile the contaminant, the greater the success. In some situations, where contaminants are less volatile, SVE enhancements such as heat injection may be required.

As shown in Figure 3-1, the soils at OU-2 are predominantly sands and gravel, with limited silts and silty sands. Based on the soil types and boring logs for wells at the site, soil moisture content is expected to be minimal, as is the soil organic carbon content.

The target contaminant groups for in situ SVE are halogenated and non-halogenated volatile organic compounds, and fuel hydrocarbons. The process is most effective for volatile compounds with a Henry's Law constant greater than 0.01 atmosphere-cubic meter per mole ($\text{atm}\cdot\text{m}^3/\text{mol}$) or a vapor pressure greater than 0.5 mm Hg (EPA, 1993b).

Data for the constituents of interest in OU-2 are presented in the RI report (Foster Wheeler, 1999b) and are reproduced here for convenience.

Constituent	Henry's Law Constant ($\text{atm}\cdot\text{m}^3/\text{mol}$)	Vapor Pressure (mm Hg)
CCl_4	0.0304	113
Freon 113	0.53	284
TCE	0.0103	77
1,1-DCE	0.0261	591

As the above information indicates, the four parameters for successful SVE remediation are met at JPL. Potential impacts to human health and the environment during the construction and implementation phases are low because the process is carried out in place. Construction is limited to installation of extraction wells, vacuum blowers, an off-gas treatment unit, and

facilities to house the off-gas treatment equipment, if needed. A schematic of SVE as it relates to OU-2 is shown in Figure 3-2.

There are no technical obstacles to implementing an SVE system at the JPL OU-2 site. This process does not carry extraordinary permitting requirements, nor does it generate waste streams that are difficult to manage. Workers and equipment are readily available for implementing this process option. In addition, the JPL site is approximately 90 percent capped, which will aid in the effectiveness of SVE by limiting surface leakage.

The overall cost for in situ SVE is typically under \$50 per ton of soil excluding treatment of off-gases and any collected groundwater (EPA, 1993b). This is an approximate estimate, and is taken only as an indication of the relative cost of implementing this process.

It is recognized that a number of SVE enhancements are available, such as air injection, heat injection, and pneumatic fracturing. However, these enhancements are typically used when conventional SVE alone is incapable of remediating the soils. Such situations include presence of silts and clays, and contaminants with limited or borderline volatilities. None of these limitations exist at OU-2, and such enhancements have therefore not been considered. Capping may also be considered as an enhancement to SVE. As mentioned above, approximately 90 percent of JPL is capped, and this should improve system performance. Further capping would have a limited effect and is not considered to be a viable enhancement.

3.3.1.2 Excavation/Incineration and Thermal Desorption

As discussed in Section 3.1.2.4, the VOC contamination at the JPL OU-2 site is distributed over a large area and to significant depths in the soil. These physical parameters severely limit the number and type of remedial technologies that can be undertaken at the site. In particular, ex-situ processes are not implementable because they require the contaminated soil to be excavated for treatment at a surface facility. Excavating 45 acres of soil at depths of approximately two hundred feet from beneath numerous permanent structures is not feasible. Incineration and thermal desorption, which are used to treat excavated soils, are not implementable because soils cannot be excavated.

3.3.2 Conclusion

Based on the discussions in Section 3.3.1, SVE can be performed as an in-situ process and is amenable to conditions at JPL. SVE will therefore be the presumptive remedy. An SVE pilot test is currently ongoing at the site, and results have been very favorable which supports the selection of SVE as the presumptive remedy. More information regarding the pilot study is presented in Section 4.2 and Appendix A.

TABLES

TABLE 3-1
ESTIMATE OF MASS OF CONTAMINANTS IN OU-2
METHOD 1

Compound	Area (ft ²)	Soil Volume (ft ³)	Pore Volume Soil (ft ³)	Soil-Vapor Concentration (µg/L-vapor)	VOC Mass (lb)
TCE	1.12E+06	2.24E+08	7.84E+07	4.1	20.1
DCE	9.20E+05	1.84E+08	6.44E+07	4.9	19.7
CCl ₄	1.96E+06	3.92E+08	1.37E+08	202	1729.4
Freon 113	1.92E+06	3.84E+08	1.34E+08	57.5	482.2
					2251.4

Assumptions:

Soil porosity - 0.35 (RWQCB, 1996).

Depth of soil - 200 feet.

Soil-vapor concentration is 1/2 maximum concentration (from Event 6 profiles).

TABLE 3-2
ESTIMATE OF MASS OF CONTAMINANTS IN OU-2
METHOD 2

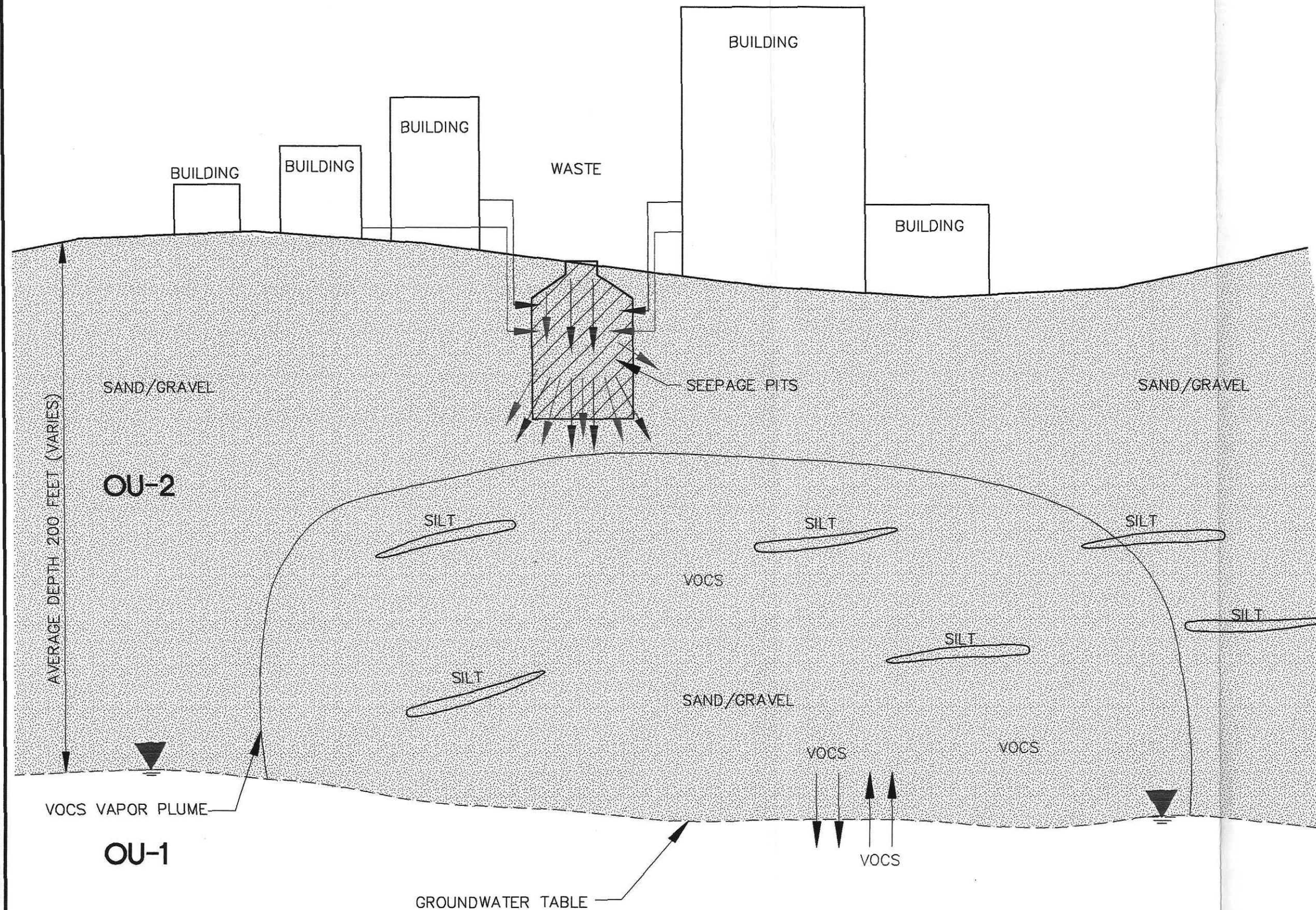
Soil Volume (ft ³)	Compound	Mass (lb)	Parameters*							
			C _T	C _G	θ _w	n	K _H	ρ _b	f _{oc}	K _{oc}
2.24E+08	TCE	123.41	5.07	4.1	0.167	0.364	0.371	1.746	0.00247	130
1.84E+08	DCE	15.08	0.75	4.9	0.167	0.364	6.237	1.746	0.00247	65
3.92E+08	CCl ₄	4139.59	97.14	202	0.167	0.364	0.998	1.746	0.00247	110
3.84E+08	Freon 113	759.67	18.20	57.5	0.167	0.364	2.41	1.746	0.00247	160
		5037.75								

Note:

* See Section 5.4 for parameter definitions.

FIGURES

i:\1572-JPL\DWG\OU2\Fs6-00\FIG3-1OU2.DWG
PLOT/UPDATE: MAY 16 2000 11:33:44



NOT TO SCALE

FIGURE 3-1

GENERALIZED SITE CONCEPTUAL MODEL
FOR OU-2

Jet Propulsion Laboratory
Pasadena, California



FOSTER WHEELER ENVIRONMENTAL
CORPORATION